Lean Six Sigma: How Does It Affect the Government?

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Lean Six Sigma (LSS) is a combination of historical methods for process improvement that focuses on the bottom line and critical-to-customer requirements. This method differs from previous process improvement approaches because it uses established engineering principles and is based on institutionalization of the approach and independent validation of claims of success. LSS has been highly successful in industry, but the government has largely ignored it. This article provides an introduction to LSS and describes how the government can benefit from using "LSS thinking" in system acquisition.

Lean Six Sigma (LSS) is the culmination of a variety of process improvement methods. These methods began in the 1920s with the development of time and motion studies, and the principles of statistical quality control. Thirty years later in the early 1950s, W. Edwards Deming and Bonnie Small developed the foundations of modern process improvement methods. Deming developed Total Quality Management (TQM). Small made the analyses of statistical quality control accessible to people who were not professional statisticians and mathematicians through her publication of "The Western Electric Rules" [1].

Prior to the development of LSS, process improvement methods were narrowly focused. They did not address the bottom line in terms of *what is critical to the customer* and *the cost of poor quality*.

Lean manufacturing focuses on eliminating *nonvalue-added* and *unnecessary* tasks. Tasks are value-added when the customer is willing to pay for them. Some tasks like invoicing are nonvalue-added, but are necessary for business operations. The lean methodology is bottom-line focused but does not address quality *per se*. Motorola [2] developed Six Sigma to drive defects to zero, but did not explicitly address the elimination of unnecessary tasks.

LSS is an approach that combines lean manufacturing and Six Sigma from a global perspective that takes both suppliers and customers into account. This approach tells us how to improve our processes in a way that considers both the costs of poor quality and issues critical to customer requirements. In addition to manufacturing processes, LSS has been very successfully used in transactional and service industries. It also directly applies to software processes, but few organizations have applied it.

The companies that are the strongest proponents of LSS include General Electric Co., Sony Corporation, Honeywell, TRW Inc., Bombardier, Johnson and Johnson, The Dow Chemical Company, Exxon Mobil Corp., J.P. Morgan Chase & Co., Citibank, GMAC Mortgage Corporation, and John Deere. In annual meetings and letters to shareholders, these companies have credited LSS with saving billions of dollars in operational expenses.

Successful LSS application requires committed leadership, education, and institutionalization. Regardless of future names and improvements, LSS as a concept will continue. The approach is flexible in the sense that the methodology is not intended to be static. LSS applies its basics to itself, i.e., just as LSS is used to continuously improve other processes, it should be used to continuously improve the improvement process.

> *"This approach [Lean Six Sigma] tells us how to improve our processes in a way that considers both the costs of poor quality and issues critical to customer requirements."*

Among process improvement approaches like TQM, business process reengineering and the Capability Maturity Model®, only LSS requires each of the following activities: (1) focusing on what is critical to the customer, (2) emphasizing the bottom line, (3) validating any claims of success, and (4) institutionalizing the process through extensive training programs and certification of expertise.

This methodology could be important to the military for several reasons:

- LSS has been proven by industry to be highly successful.
- Major prime contractors have implemented LSS, including The Boeing Company, Raytheon Company, Lockheed Martin Corporation, TRW, Honeywell, and Northrop Grumman Corporation.
- LSS can help the military operate more efficiently.
- LSS thinking can be applied to acquisitions and software intensive systems.

This article provides some answers to the following questions:

- What is LSS?
- Why should the government care about LSS?
- How can LSS be applied to acquisition?

What Is LSS?

Six Sigma was developed by Motorola Inc. in the mid-1980s to control variability in processes. Simply stated, Motorola concluded that they could not compete with the Japanese using their current concept of quality. The cost of poor quality was too high. They developed Six Sigma to produce essentially zero defects in their products.

Lean manufacturing inspects the process by analyzing each task or activity to determine whether it is value-added, is not value-added but necessary, or is not value-added. A value-added activity is something for which the customer is willing to pay. An example of a value-added activity is the maintenance of a satellite operations center. If a contractor was maintaining this center, then an example of a nonvalue-added but necessary activity is an invoice payment. Activities that neither add value nor are necessary should be eliminated.

When a major program review is held, like the critical design review for the software of a major system, it is common for the review to be attended by 150 high-priced people and to last for a week. These reviews are frequently dog-and-pony shows in which no really critical review takes place. A typical cost for this review is more than $8/second (more

than $1 million for the week). Does this review add value? How should it be changed to add value? LSS thinking addresses these questions.

LSS is a defined approach that synthesizes the use of established tools and methods. Its methods are generally divided into two approaches. One approach is called *design for Six Sigma*. It is generally used when designing new systems or processes.

The other approach, used for process improvement, is called the *define-measure-analyze-improve-control* approach, which represents five phases. Some organizations (and I agree with them) use six phases. The difference between these representations is that the second approach divides the define phase into vision and define. These six phases of LSS are described below.

- **Vision.** This phase is used to identify critical-to-customer factors, teams, and key stakeholders; to describe the business impact; and to plan the process improvement project.
- **Define.** This phase focuses on defining the as-is process. Frequently, processes are understood by experienced personnel but are not actually written down. Simply gathering a group of key people in a room and asking them to define a process often improves it. Sometimes the improvements are significant, and the team decides that it is good enough – no further work is necessary.
- **Measure.** The purpose of this phase is to measure the existing process. Without these measurements, it is impossible to determine how much a process is improved or to validate savings. This phase is critical to future analyses and suggested process improvements.
- **Analyze.** During this phase, the causes of poor quality are determined and analyzed. Each step of the process is assessed to determine waste from a lean perspective. Problems are determined from historical data and employee knowledge. Fishbone charts, also called cause-and-effect charts, are used to identify the most likely causes of the defects. The process is usually simulated to determine bottlenecks and resource utilization, and the cost of defects. These analyses form the basis for design of experiments, regression analysis, and other techniques used to evaluate potential improvements in the next phase.
- **Improve.** The focus of this phase is to determine process improvements. Processes are assessed from the perspectives of whether (1) each task adds value to the product or service, (2) there is a more cost-effective way of performing the process, and (3) the process meets or accounts for requirements critical to the customer. Typically, the process is modeled and simulated. New ideas are tried out in simulation before they are implemented. Sometimes it is necessary to perform a design-of-experiments analysis to determine ways to improve a process. This allows the analyst to determine the value of adding people or resources to a given task or taking them away from another task. It also allows the analyst to look at fundamental changes to the process. These analyses are conducted from a bottom-line perspective.
- **Control.** During this phase, the improved process is implemented in a controlled manner. Data are taken to verify that the proposed improvement (previously validated through simulations) is real. The financial member of the team serves as an independent auditor and validates the savings. Frequently, the process is initially implemented as a prototype before full implementation.

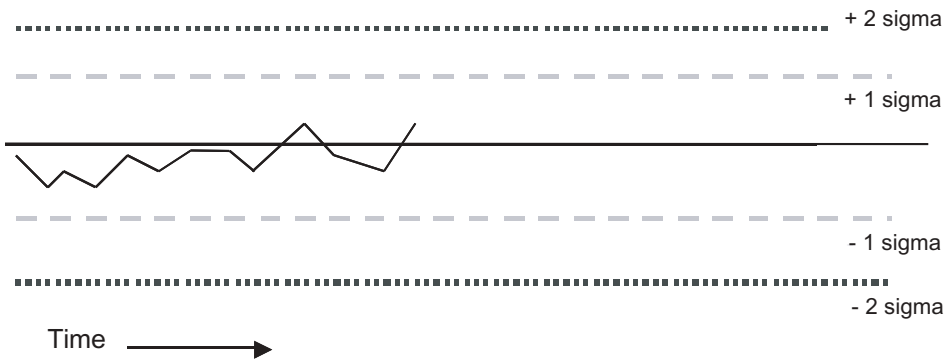

Figure 1: *Sample Telemetry Run-Chart*

"Lean manufacturing inspects the process by analyzing each task or activity to determine whether it is value-added, is not value-added but necessary, or is not value-added."

Each of these phases uses a defined methodology. Training to become an expert in LSS takes several weeks spread over a five-month period. Between the classes, students work on an actual project, receiving consulting advice from the trainer as necessary. When training is completed, the student will have implemented a successful LSS project. After completing a second project in which the student is the leader, and taking an exam, the student is certified as a LSS expert, or equivalent to a *black belt* in the field. There are lesser levels of training for people who help on LSS projects but are not the leaders. LSS organizations provide training internally, but consulting companies are generally used in the early stages of implementing LSS.

This article has talked about LSS as a methodology, but it is more than that. It is a way of thinking that is illustrated in the following way. Consider the telemetry run chart shown in Figure 1. A satellite operator looking at this chart in real time thinks that everything looks pretty good. In fact, it looks great – the process is running well within its control limits.

If we apply LSS thinking to this chart, we begin to analyze the process statistically. Applying well-known run-chart analysis techniques [1] (which could be automated), we see that a statistically significant event has already occurred and another might occur soon. These events are identified in Figure 2 (see page 10).

The fact that a statistically significant event has occurred does not necessarily mean that something bad has happened. It does mean that there is an anomaly that needs explanation. This analysis would trigger involvement by satellite engineers to resolve the anomaly. If the event is caused by something bad, the engineers may be able to resolve it before additional damage is done to the satellite. This example shows how LSS thinking can lead to early detection of anomalies.

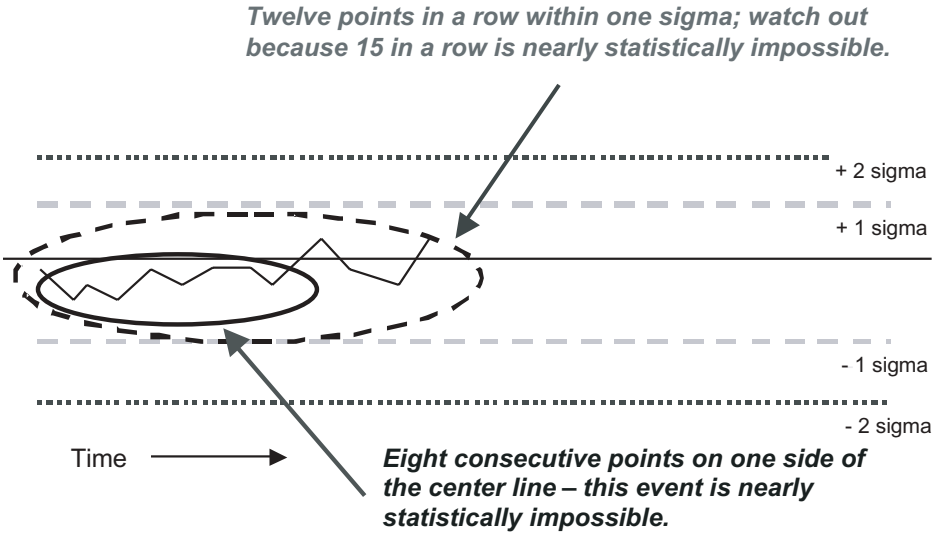

Figure 2: *Run-Chart With Statistical Analyses Superimposed*

Why Should the Government Care About LSS?

LSS is a best practice for process improvement. It applies to all processes – manufacturing, software, operational, transactional, and service processes. All the major space contractors use LSS, including Lockheed Martin, Raytheon, Boeing, TRW, Northrop Grumman, and Honeywell. Furthermore, the presidents of Lockheed Martin, Honeywell, Raytheon, and TRW are among the leading advocates for LSS in the defense industry.

Many of these companies actively promote its use. At Lockheed Martin, their LM21 Operating Excellence program is based on LSS. The Raytheon Learning Institute is offering LSS services to external companies as well as for training people throughout Raytheon. Honeywell has integrated LSS into its software processes. TRW has a major training program underway that will touch every TRW employee. To answer a question with a question: If the major prime contractors believe in LSS and are applying it in both their government and commercial business, why has the government largely ignored it?

Lt. Gen. Brian A. Arnold, commander, Space and Missile Systems Center, Los Angeles Air Force Base, was recently quoted as saying, "I will tell you that in virtually every one of our major programs we are out of control on cost and schedule" [2]. LSS is designed for process improvement, but its principles can help maintain both cost and schedule control. LSS is based on two perspectives: requirements that are critical to the customer, and satisfying these requirements at the lowest possible cost.

The first perspective limits requirements creep – a major driver of both cost and schedule growth. Before imposing a new requirement, either in the specification development phase or in the system development phase, the program manager should ask, "Is this requirement really critical to the customer?" Another way of asking this is to determine what the customer is willing to pay for the additional requirement. The *nice-to-have* requirements frequently fall by the wayside under this type of scrutiny.

The second perspective is more complicated because its answer depends on a total system/result perspective. This perspective forces us to think about the cost of poor quality. Providing requirements at the lowest possible cost is a driver for using a defined systems engineering methodology. A defined methodology with good documentation and built-in quality significantly lowers the cost of operations and maintenance. This claim is not a *logical* but *subjective conclusion*. Organizations that have, for example, implemented the Software Engineering Institute's Capability Maturity Model® (CMM®) to Level 4 or 5 have the data to prove it. LSS companies also have the data to prove it.

Knowledge of LSS is critical to government agencies. This knowledge could be applied to do the following:

- Help operations groups improve their processes.
- Help the transactional groups (e.g., finance, contracts, and human resources) improve their processes.
- Specify contractor incentives to be included in awards.
- Understand what performance information to request from contractors.
- Evaluate contractor proposals.
- Assure that contractors apply best practices to their customers' programs.

A further discussion of how to apply LSS to acquisition follows in this article.

How does LSS apply to the military? The Advanced Extremely High Frequency (AEHF) satellite communications system will cost $3.19 billion to produce two satellites, each with 10 years of operational life [3]. Assume that there will be no cost overrun, that each satellite will be successfully launched with full operational capability for its entire life, and that there are *no* operations cost. With these assumptions, the straight-line amortized cost of this satellite system will be about $437,000 per day per satellite throughout its operational life. A 95 percent uptime means that the downtime costs $160 million (or one year of operation). A 99 percent uptime means that the downtime costs $32 million (or 2.4 months of operation). LSS, or 99.9997 percent uptime, means that the downtime costs $6.57 (or 1.3 seconds of operation). The impact of downtime on military operations is immeasurable.

For some organizations, applying LSS seems pretty clear. Any group operating and maintaining an information technology enterprise cannot survive without processes. These processes include helpdesk processes, logistics processes, property management processes, and so on. These activities sound like simple, mundane stuff until you consider their size. The information technology enterprise of one of our customers requires more than 1,200 people for operations and maintenance. Other potential applications are the human resources and financial processes. Note that each of the processes mentioned use a substantial amount of software.

How Does LSS Apply to System Acquisition?

Stating that LSS applies directly to system acquisition because it is a process is correct, but it is a cop-out. The focus of this section is how to use aspects of LSS during pre-proposal activities, proposal evaluation, and program evaluation. The government cannot require companies to use LSS, just like they cannot require companies to use the CMM. However, these items can be used as factors during an evaluation.

Pre-Proposal Activities

The greatest value of LSS thinking is obtained during the pre-proposal stage. This is the time when program managers can think proactively. During this phase, key decisions are made involving the structure of the future contract, the meas-

ures that will be used to evaluate contractor performance, and the criteria for evaluating bidders.

Every prime contractor has a set of corporate engineering and management processes that reflect best practices. Most of these contractors have policies about implementing LSS. Structure your request for information (RFI) in a way that gets the contract personnel to use these processes. Some of the questions that could be included in an RFI include the following:

- What are your corporate processes and policies related to LSS or process improvement?
- What corporate processes will be used on this contract?
- How will the performance of these processes be measured?
- How do you improve your processes during the performance of a contract?
- How do you assure that these corporate processes are used and improved?
- Are the key people who will be working on this effort trained and certified in your corporate processes?
- How will you measure the improvement?
- What is your process and criteria for handling changes to requirements?
- What is your procedure for determining the cost of poor quality?
- What recommendations do you have for structuring an incentive clause?
- What recommendations do you have for measuring contractor performance?

Proposal Evaluation

Determine the extent to which the contractor is using LSS thinking. For example, in answering the question on requirements changes, does the contractor address the issue of whether a change is critical to the customer? If so, then the cost and schedule impact of every change needs to be determined. The contractor then needs to meet with the government and ask whether the government is willing to pay for the change. The cost for this change is more than simply money. From an oversight perspective, additional cost means overrun. It usually does not matter whether the cost is due to a new, critical requirement. The contractor needs to determine the likely savings resulting from future process improvements. These cost savings might offset the budgetary impact of a new critical requirement.

Government program offices need to understand that they need to work with the contractor on the issue of requirements criticality. Many contractors think that any change requested by the contracting officer's technical representative is critical – the acquisition office is the customer. From a government perspective, there are multiple customers, including the users (frequently operational forces), Congress, and other agencies.

The contractor needs to be willing to challenge whether a new requirement is really critical. Current contracting approaches force contractors to bid unreasonably low under the assumption that the deficit will be eliminated through engineering change proposals. That is a losing approach because overruns are assured. Think about the win-win approach used in LSS. Use incentive fees for contractors to benefit from reducing total cost to the government. Fund new critical requirements to the maximum extent possible from the government's share of the savings resulting from process improvement.

Looking at the cost of poor quality helps program managers address difficult questions. Budgetary pressures and external policies frequently drive program managers to make decisions that they know are *penny-wise but pound-foolish*. For example, by separating development costs from operations and maintenance costs, program managers are driven to make decisions favoring reduced development cost even though a severe impact might be realized in operations. A detailed cost of poor quality analysis may enable program managers to justify different decisions. These types of decisions significantly impact the system that will be built.

Program Evaluation

If LSS thinking was used during the preproposal and proposal evaluation phases, its use during program evaluation is mundane. The metrics are defined, so the government can use them to evaluate contractor performance. This approach seems straightforward and simple, but its proper execution requires program managers to have some training in LSS; the preferable level is equivalent to a *green belt*. This training typically involves one week of classwork followed by working on a LSS project in a support role.

Obtaining this week of training is generally not a problem, but many program managers will not have the time to actually work a process improvement effort using LSS. I recommend that program managers take a one-week course on LSS. This training will provide a more thorough understanding of the process, and they will be able to ask appropriate questions of the contractor to verify that the methodology is actually being used.◆

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Additional Reading

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